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Field-store standards conversion: conversion between television signals with different field frequencies using ultrasonic delays

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SUMMARY

At the present time, standards conversion between television signals having different field frequencies is carried out by the image transfer method. This method results in a significant impairment of picture quality and the converters used require considerable maintenance and adjustment. In this report new methods of conversion are discussed which should overcome these disadvantages. The converters proposed use fused quartz ultrasonic delays capable of storing a complete field at the input standard and can be conveniently termed "field-store" converters.

1. INTRODUCTION

Since different television standards are used in various parts of the world, it is necessary to provide apparatus for standards conversion whenever programmes are exchanged.[1] Until recently, these converters have comprised a cathode-ray tube/camera combination usually referred to as an image transfer converter. Image transfer converters, however, result in a measure of picture impairment which cannot be regarded as acceptable for all future standards conversion requirements.[1] In particular, the transmission of high-quality pictures over long distances is now possible by means of earth satellites, and better methods of standards conversion are needed to exploit these facilities to the full.

Conversion between television standards having identical field frequencies but different numbers of scanning lines has already been achieved without the use of a cathode-ray tube and camera.[2,3,4] In this case, the conversion is achieved using an assemblage of electronic switches and passive network storage elements which have sufficient capacity to write, read and store a whole line of a television signal and for this reason the converters are termed "line-store" converters. However, conversion between television standards having different field frequencies presents a more difficult problem. In this case, the converter must have the capacity to write, read and store a complete field of the input standard and this requires a storage capacity some two or three hundred times greater than that provided in a line-store converter. For this reason a converter for conversion between standards having different field frequencies which does not use a cathode-ray tube/camera combination can be conveniently termed a "field-store" converter.

An image-transfer converter, designed for conversion between standards with different field frequencies suffers from certain disadvantages, the chief among which are:

(a) A complicated line-up procedure and frequent adjustment by an operator are necessary to ensure good performance.

(b) Movement blur is very evident.

(c) Flicker due to beats between the input and output field frequencies cannot be completely eradicated.

(d) There is a significant loss of resolution.

Proposals have been made for field-store converters[5,6,7,8,9] which would overcome, or largely overcome these disadvantages. In addition, a monochrome field-store converter could provide a basis for the design of a field-store converter for colour signals.[8] The possibility of colour conversion by the field-store process is particularly important since the difficulties involved in a colour conversion by the image-transfer process are formidable.

At the present time, the storage capacity required by a field-store converter can only be obtained by the use of ultrasonic delays* or magnetic recording devices. Of the two methods, the fused quartz ultrasonic delay[10] offers the required performance with more certainty and the proposals discussed in this paper assume this type of storage.

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* To avoid confusion with a television scanning line, a delay line used to delay or store television signals is referred to simply as a "delay".

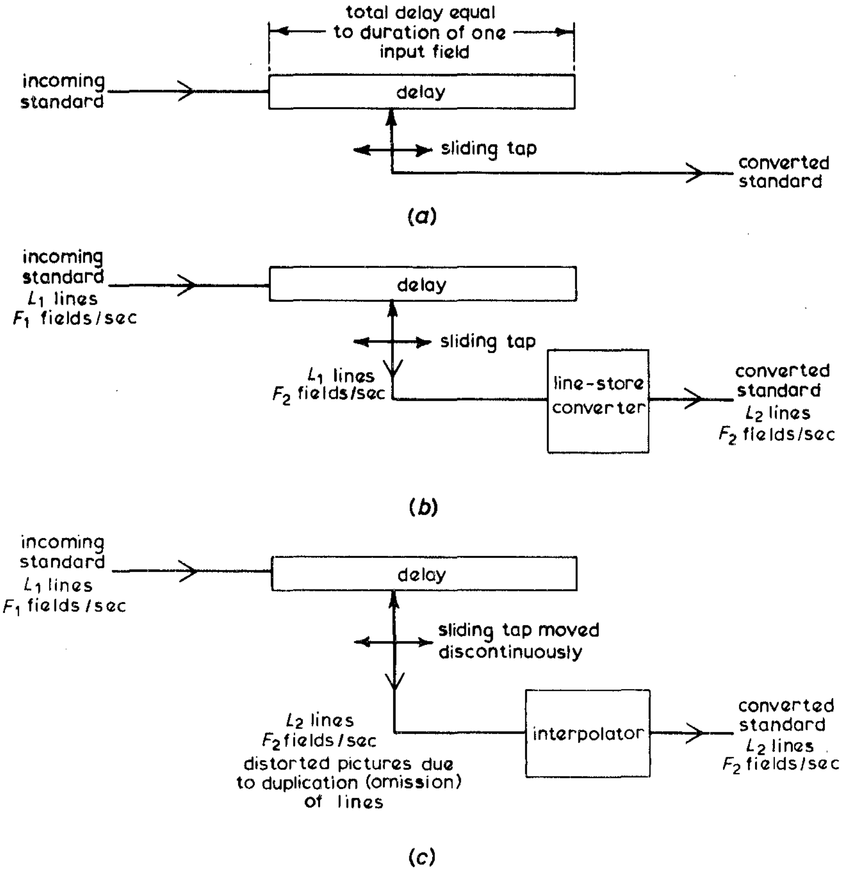

total delay equal to duration of one input field
incoming standard
delay
sliding tap
converted standard
(a)
incoming standard L_1 lines F_1 fields/sec
delay
sliding tap
L_1 lines F_2 fields/sec
line-store converter
converted standard L_2 lines F_2 fields/sec
(b)
incoming standard L_1 lines F_1 fields/sec
delay
sliding tap moved discontinuously
L_2 lines F_2 fields/sec
distorted pictures due to duplication (omission) of lines
interpolator
converted standard L_2 lines F_2 fields/sec
(c)

Fig. 1 - Basic forms of field-store converter

(*a*) Conversion of field frequency by delay with sliding tap
(*b*) Conversion of field frequency and line standard by delay with sliding tap and ancillary line-store converter
(*c*) Conversion of field frequency and line standard by delay with tap moved discontinuously and ancillary interpolator

Nevertheless, magnetic store devices merit further consideration since, if their performance could be made satisfactory, they would probably provide more cheaply the larger delays required.

It should be mentioned finally that it will doubtless become possible in the future to provide the storage required by a field-store converter by digital means. However, at the present time, the provision of sufficient storage capacity together with sufficiently high rates of reading and writing presents many problems.

2. THE PRINCIPLES OF FIELD-STORE CONVERSION

The principles of field-store conversion are quite general and may be applied to any television standards. However, for the purpose of illustrating the conversion process, the American 525 line/60 field, the European 625 line/50 field and the British 405 line/50 field standards will be used. For convenience, these standards will be referred to as 525/60, 625/50 and 405/50 respectively.

For the purposes of explanation, Fig. 1(*a*) shows a simple system[7,8] which could theoretically be used to convert the field frequency of a television signal. The arrangement consists of a delay capable of storing one complete field at the input standard. The input standard is applied to the input of the delay and the output standard (the converted picture) is taken from a sliding tap. If the sliding tap is moved from the input of the delay (i.e., the point of zero delay) towards the far end, then the output from the tap will comprise television fields whose duration has been increased. Each input field will appear at the terminals of the sliding tap expanded in time, and the number of output fields per second must therefore be less than the number of input fields; it will therefore be necessary at intervals to omit a complete input field. Thus, for example, if the conversion were from a 60 field/second to a 50 field/second standard, it would be necessary to omit every sixth input field. The tap would traverse the delay in the duration of six input fields (giving five output fields whose durations are expanded in the ratio 6 : 5). At the conclusion of the fifth output field, the sixth input field would be completely stored in the delay and could be omitted by switching the sliding tap back to the input of the delay.

A delay with sliding tap could also be used to convert from one standard to another having more fields per second. In this case, the tap would move from the end of the delay back towards the input, thus compressing the input fields in time. Since the number of output fields occurring every second will now exceed the number of input fields, it will be necessary at intervals to generate the missing output field by a repetition of one of the input fields. For example, in the case of conversion from a 50 field/second to a 60 field/second standard, an input field would first be stored in the delay. The sliding tap would then traverse the delay during the duration of the next five input fields, giving six output fields whose durations are compressed in the ratio 5 : 6. At the conclusion of the sixth output field, the sixth input field will be completely stored in the delay and can be "re-read" by switching the sliding tap contact to the far end of the delay and re-commencing the cycle.

In the arrangement described, the number of fields per second would be converted, but the number of lines in the input and output pictures would be identical. In general, however, it is necessary to convert between standards in which both the number of fields per second and the number of lines per field are different and to meet this requirement, there are two methods whereby the operation of the delay with sliding tap could be extended:

(i) It would be possible to follow the delay with sliding tap by a line-store converter as shown in Fig. 1(*b*). Thus, for example, a conversion from the American 525/60 standard to the British 405/50 standard could be carried out in two stages. The delay with the sliding tap would convert from the 525/60 standard to a 525/50 standard and the line-store converter would perform a conversion from the 525/50 standard to the 405/50 standard.

(ii) It would be possible to carry out the complete conversion using the delay with sliding tap alone, without an additional line-store converter. Since the number of lines per field and the number of fields per second must both be changed, the conversion must involve the omission or insertion of some lines in each field, and the insertion or omission of fields. These processes could be achieved if the sliding tap on the delay of Fig. 1(*a*) were moved discontinuously as indicated in Fig. 1(*c*). For example, if the conversion were from an input 625/50 standard to an output 525/60 standard, it would be necessary to omit 50 lines from each input field and in addition to duplicate every fifth input field. During the period of each line at the output standard, the sliding tap would move towards the input of the delay at such a velocity that the duration of the line would be compressed from 64 μs (the European 625-line standard to 63 31/63 μs (the American 525-line standard). Each time an input line had to be discarded, the tap would "jump" towards the input of the delay so that the total delay between the input and the tap would be reduced by 64 μs, thus omitting the line stored in that section of the delay. This movement would continue throughout the duration of a cycle of five input fields, during which time the tap would have travelled back from the end to the input of the delay. The tap would then be switched back to the end of the delay to recommence the cycle and would provide the sixth output field by a repetition of the fifth input field, which would be at that moment completely stored in the delay. A similar arrangement could be used for the converse case of conversion from the 525/60 standard to the 625/50 standard.

In method (ii), the discontinuous movement of the sliding tap would convert both the number of fields per second and the number of lines per field correctly but a displayed picture of the output standard would be distorted on account of the discontinuities resulting from the omission or duplication of lines of the input standard. For example, a sloping edge would be reproduced with a serration at each point where an input scanning line had been omitted or duplicated. Some form of interpolation between the lines of the input standard is required to remove this geometrical distortion and an additional interpolator network is therefore shown in Fig. 1(*c*). In method (i), however, interpolation would be provided by the line-store converter[2,3,4] and an additional interpolator is not therefore required. In both methods (i) and (ii) input fields are omitted or duplicated at intervals and this will result in a jerky portrayal of moment.[8] Thus, in addition to the interpolation between the lines of the input standard to remove geometrical distortion it may be necessary to provide another form of interpolation between successive fields of the input standard to avoid a jerky portrayal of motion.

3. INTERPOLATION

It has been pointed out in Section 2 that two different forms of interpolation may be required in the field-store conversion process. It is felt however that interpolation between the scanning lines of the input standard with the object of removing geometrical distortion,[2] is more important than interpolation between successive fields of the input standard to provide a smooth portrayal of motion. This is because the geometrical distortion will be visible on many scenes whereas a jerky portrayal of movement will only affect scenes containing rapid movement or fast panning. To simplify a discussion of the interpolation problem, therefore, it will be assumed that only interpolation between the scanning lines of the input standard is necessary. It should, however, be noted that it would probably be necessary to provide some form of movement interpolation in a field-store converter for operational use.

In Section 2 two basic methods of achieving field-store conversion have been described:

(i) In which a delay with sliding tap is used to convert the field frequency. The conversion of the number of scanning lines is then carried out in a line-store converter which provides the interpolation between the lines of the input standard.

(ii) In which the complete conversion is carried out in the delay with sliding tap and an additional interpolator is required.

At first sight, it would seem that method (i) (Fig. 1(*b*)) provides the simplest solution to the problem of field-store conversion since the problems of line-store conversion have been solved and a suitable converter could readily be built. However, it can be shown that the use of a line-store converter places severe restrictions on the methods of interpolation that can be used, both as regards the removal of geometrical distortion and the correction of a jerky portrayal of movement. On the other hand, the type of field-store converter outlined in (ii) (Fig. 1(*c*)) allows considerable freedom of choice in the interpolation arrangements and is therefore likely to form the basis of converters designed for operational use. For this reason, an explanation of the problems of interpolation and the means whereby they may be overcome assumes a field-store converter based on method (ii).

3.1. Interpolator Circuits

The interpolation process for a field-store converter using method (ii) could in principle be carried out either before or after the delay with sliding tap. Investigation has shown, however, that it would be most convenient instrumentally to perform the interpolation before the delay with sliding tap.[7] The requirements of the interpolation process can be determined by superimposing rasters of fields of the input and output standards which have the same physical dimensions. This is illustrated in Fig. 2 for the case of conversion between the American 525/60 and European 625/50 standards and it will be seen that the rasters exhibit a spatial beat pattern of line position. At intervals, two lines of the 625/50 standard fall between two adjacent lines of the 525/60 standard and it is on these occasions that a new line must be inserted when converting from the 525/60 to 625/50 standard. On

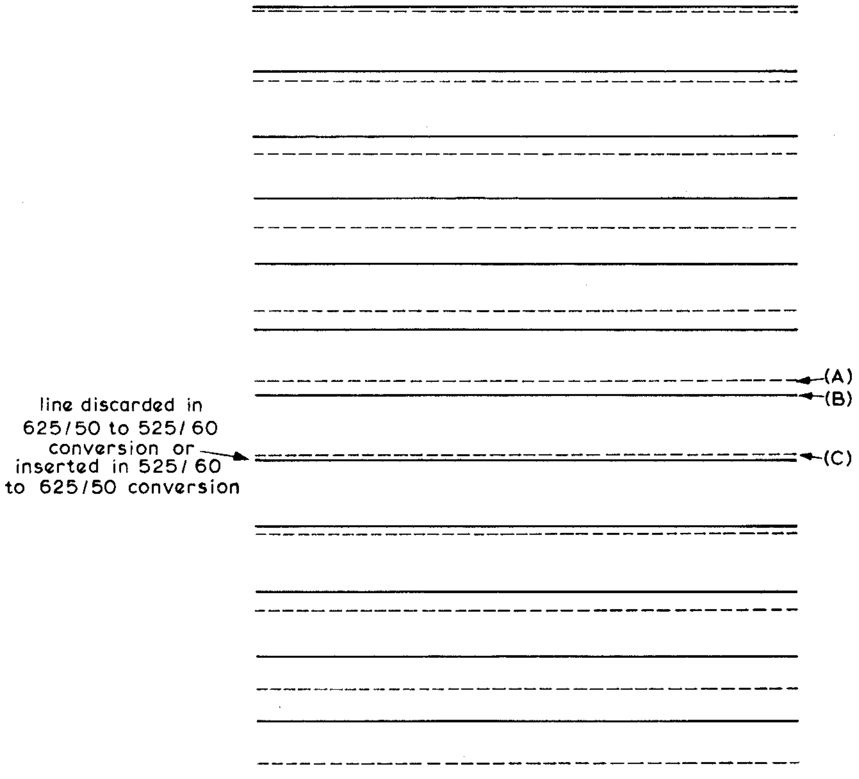

line discarded in 625/50 to 525/60 conversion or inserted in 525/60 to 625/50 conversion
(A)
(B)
(C)

Fig. 2 - Superimposed field rasters of the 625/50 and 525/60 standards

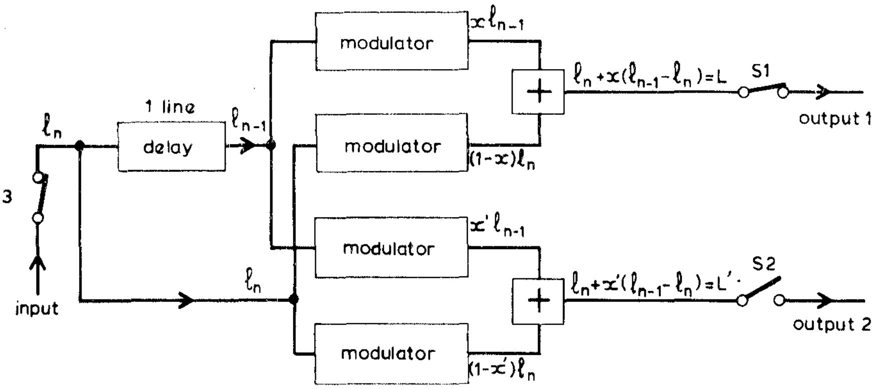
———— Scanning lines of 625/50 standard
------ Scanning lines of 525/60 standard

the other hand, at these intervals, there is no 525/60 line between two adjacent lines of the 625/50 standard and it is on these occasions that a line must be omitted when converting from the 625/50 to the 525/60 standard. A diagram of the form of Fig. 2 also indicates the proportions of the input scanning lines which must be used in the interpolation process. For example, in a conversion from the 525/60 standard to the 625/50 standard, the line marked "B" would need to comprise a large proportion of line "A" and a small proportion of line "C".

The design of the interpolator may therefore be based on a diagram of the type shown in Fig. 2 and two cases must be considered:

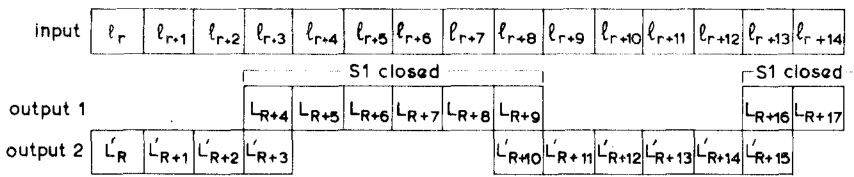
(i) The Number of Lines of the Output Standard Exceeds the Number of Lines of the Input Standard

During the period of each field at the input standard there will be a number of occasions when a new line must be inserted and the interpolator must therefore produce two lines simultaneously. Thus, for example, in the case of 525/60 to 625/50 conversion the interpolator must produce two lines simultaneously fifty times during each input field. It is important to note, however, that when two lines are produced simultaneously by the interpolator they cannot be identical since they will eventually occupy different positions on a display of the output standard as is illustrated in Fig. 2. The interpolator for a 525/60 to 625/50 conversion[7] is illustrated in Fig. 3(*a*) and is seen to have two outputs which produce sequences of lines that overlap on the occasions when an additional line is to be provided; this is shown in Fig. 3(*b*). The interpolator must also be arranged so that an input field is occasionally discarded (if the output field frequency is lower than the input field frequency) or duplicated (if the output field frequency is higher than the input field frequency). Since a conversion from the 525/60 standard to the 625/50 standard is assumed, Fig. 3(*c*) shows that every sixth field at the input standard is discarded; this is necessary since six fields at the input standard occupy the same duration as five fields at the output standard.



(i) ℓ_{n-1} and ℓ_n denote voltages as functions of time of two successive lines at the input standard.
(ii) x and x' denote the proportions of ℓ_{n-1} required for interpolation
(iii) S1 and S2 are closed during partially overlapping sequences of six (occasionally seven) input lines.
(iv) S3 is open during each 6th input field.

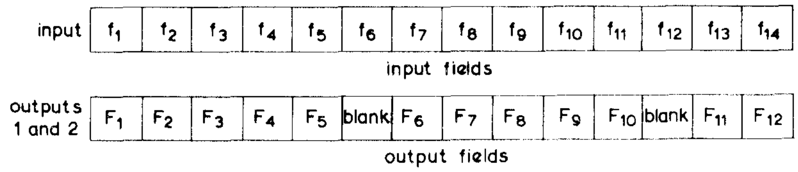
(*a*)



input	ℓ_r	ℓ_{r+1}	ℓ_{r+2}	ℓ_{r+3}	ℓ_{r+4}	ℓ_{r+5}	ℓ_{r+6}	ℓ_{r+7}	ℓ_{r+8}	ℓ_{r+9}	ℓ_{r+10}	ℓ_{r+11}	ℓ_{r+12}	ℓ_{r+13}	ℓ_{r+14}
				S1 closed										S1 closed	
output 1				L_{R+4}	L_{R+5}	L_{R+6}	L_{R+7}	L_{R+8}	L_{R+9}					L_{R+16}	L_{R+17}
output 2	L'_{R}	L'_{R+1}	L'_{R+2}	L'_{R+3}					L'_{R+10}	L'_{R+11}	L'_{R+12}	L'_{R+13}	L'_{R+14}	L'_{R+15}	
	S2 closed									S2 closed					

(i) Dashes on output lines from output 2 denote different interpolation from output 1
(ii) Output lines are derived from two input lines eg. L'_{R+1} is derived from ℓ_r and ℓ_{r+1}, and L'_{R+3} and L_{R+4} are both derived from ℓ_{r+2} and ℓ_{r+3}.

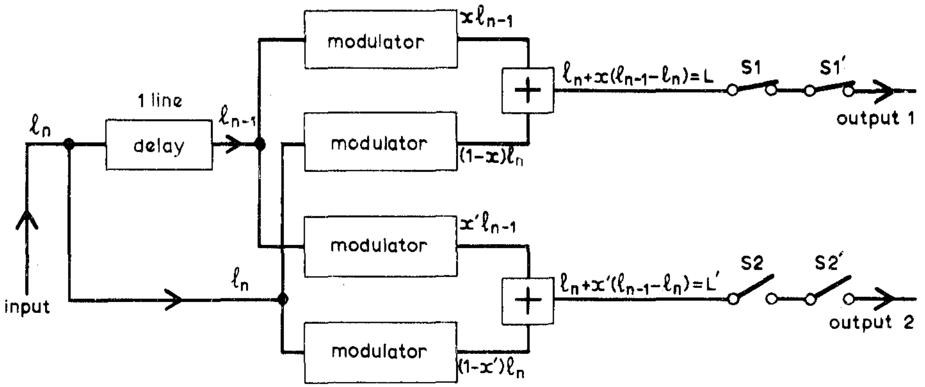
(*b*)



input	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}
	input fields													
outputs 1 and 2	F_1	F_2	F_3	F_4	F_5	blank	F_6	F_7	F_8	F_9	F_{10}	blank	F_{11}	F_{12}
	output fields													

(*c*)

Fig. 3 - Interpolation for 525/60 to 625/50 conversion
(*a*) Schematic of interpolator (*b*) Typical sequences of input lines and interpolated output lines
(*c*) Sequences of input and output fields



(i) ℓ_{n-1} and ℓ_n denote voltages as functions of time of two successive lines at the input standard.
(ii) x and x' denote the proportions of ℓ_{n-1} required for interpolation.
(iii) S1 and S2 are closed during partially overlapping sequences of six fields.
(iv) S1′ and S2′ are open when a line is to be discarded (every 6th or 7th line)

(a)

input	ℓ_r	ℓ_{r+1}	ℓ_{r+2}	ℓ_{r+3}	ℓ_{r+4}	ℓ_{r+5}	ℓ_{r+6}	ℓ_{r+7}	ℓ_{r+8}	ℓ_{r+9}	ℓ_{r+10}	ℓ_{r+11}	ℓ_{r+12}	ℓ_{r+13}	ℓ_{r+14}
						S1′ open						S1′ open			
output 1	L_R	L_{R+1}	L_{R+2}	L_{R+3}	L_{R+4}	blank	L_{R+5}	L_{R+6}	L_{R+7}	L_{R+8}	L_{R+9}	blank	L_{R+10}	L_{R+11}	L_{R+12}

(b)

(i) Output 1 only shown. Output 2 is similar but has different interpolation.
(ii) Outputs 1 and 2 deliver lines simultaneously every 5th output field.

input	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
				S1 closed										S1 closed	
output 1				F_5	F_6	F_7	F_8	F_9	F_{10}					F_{17}	F_{18}
output 2	F_1	F_2	F_3	F_4					F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	
	S2 closed								S2 closed						

(c)

Fig. 4 - Interpolation for 625/50 to 525/60 conversion
(*a*) Schematic of interpolator (*b*) Typical sequences of input lines and interpolated output lines
(*c*) Sequences of input and output fields

(ii) The Number of Lines of the Input Standard Exceeds the Number of Lines of the Output Standard

Fig. 4(*a*) shows the interpolator arrangement[7] for the case of a 625/50 to 525/60 conversion and Fig. 4(*b*) shows the corresponding sequences of lines at the input and output of the interpolator. It will be seen that in this case the interpolator output consists of sequences of interpolated lines, each sequence being followed by a blank of line duration so that the number of lines per field is reduced to the number required by the output standard. Since, in the example given, the conversion is from the 625/50 standard to 525/60 standard, two interpolator outputs must be provided which produce the overlapping sequences of fields shown in Fig. 4(*c*). It must be noted, however, that although two simultaneous fields are generated at intervals from the same input field they must not be identical when emerging from the output. They will eventually be interlaced to form a complete picture at the output standard and their spatial positions will therefore differ.[8] The lines of the two fields must therefore be derived simultaneously from different proportions of the lines of the same input field.

The interpolators of Figs. 3 and 4 provide scanning lines appropriate to the output standard by combining adjacent scanning lines in each field of the input standard in appropriate proportions. Thus in the interpolators, line period delays are shown which make available spatially adjacent points on adjacent lines in the same input field simultaneously. It is known, however, that certain undesirable flickering effects associated with the field-store process[7] would be eradicated if the interpolation were made between adjacent lines of a picture instead of adjacent lines of a field. In the interpolators of Figs. 3(*a*) and 4(*a*), this could be achieved by replacing the line period delays with delays of the duration of a field plus or minus half a line. However, if the interpolation were carried out in a line-store converter following the delay with sliding tap, interpolation between adjacent lines of a picture would result in very considerable instrumental complications. For this reason, there-

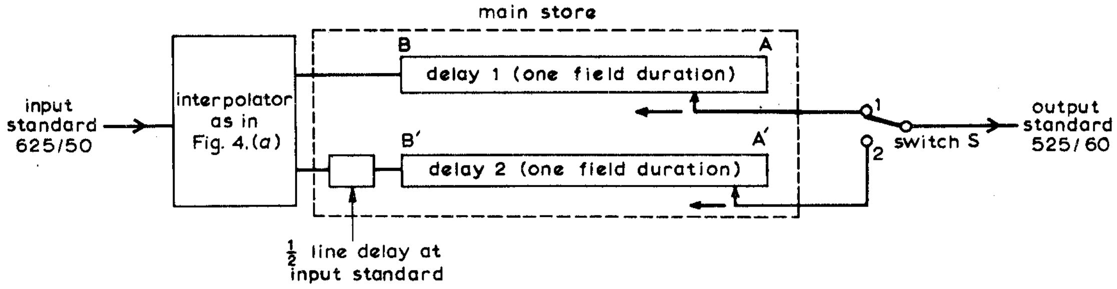

main store
B
A
delay 1 (one field duration)
input standard 625/50
interpolator as in Fig. 4.(a)
B′
A′
delay 2 (one field duration)
1
2
switch S
output standard 525/60
½ line delay at input standard

Fig. 5 • 625/50 to 525/60 converter with interpolation and correction for interlace.

fore, the form of converter shown in Fig. 1(*c*) which uses an interpolator preceding the delay with sliding tap has some advantage over that shown in Fig. 1(*b*) which incorporates a line-store converter.

3.2. Interlacing

All broadcast television systems use an interlaced picture and this poses problems in the design of the interpolator.[7] When a sequence of fields at the output standard is derived from an interlaced sequence of input fields the output fields will be correctly interlaced. However, when an input field is omitted, or duplicated, the interlace of the sequence of input fields is lost. Thus without some form of timing correction, each sequence of output fields will not be interlaced with the preceding and succeeding sequences.

The fact that input fields are occasionally omitted or duplicated makes it necessary to derive both even and odd output fields from a given input field and it has already been pointed out that the occasions on which the insertion and omission of lines must be made can be determined by superimposing rasters of the two standards. If the raster of a particular field at the output standard (say an even field) is superimposed on the rasters of even and odd fields at the input standard, the occasions on which two lines of one standard will fall between two lines of the other will differ. Thus the omission or insertion of lines in the output signal must be made at different times in the conversion cycle.

The manner in which the difficulties posed by interlace can be overcome may be illustrated by reference to conversion from the 625/50 to the 525/60 standard using the type of converter illustrated in outline in Fig. 1(*c*) and the interpolator shown in Fig. 4(*a*). The arrangement is shown in Fig. 5 and it will be seen that the two outputs of the interpolator are each connected to a delay with sliding tap. Two delays are shown to simplify the explanation but in practice one delay could be used. Successive overlapping sequences of six interpolated fields emerge from outputs 1 and 2 of the interpolator as shown in Fig. 4(*c*). These sequences which are interpolated so that they will form an interlaced picture at the output standard are fed into delay 1 and delay 2. The successive sequences of six output fields are reduced in duration by delays 1 and 2 so that they become a continuous sequence when taken alternately from the two delays by operation of switch "S". It will be seen, however, that a delay of the duration of a half-line at the input standard is connected in series with one of the delays. This additional storage element corrects the timing of the successive sequences of six output fields so that they are correctly interlaced.

4. THE BINARY DELAY STORE

The basic methods of field-store conversion described in Section 3 assume the use of a delay with sliding tap. These methods cannot be realised directly in practice, however, since at the present time it is not possible to construct a satisfactory continuously-variable field delay. It is, however, possible to construct continuously variable delays of the duration of a television line and such arrangements form a part of line-store converters. It is therefore possible to construct a field delay from a number of small, equal delays "T" in series with a continuously variable delay of maximum value T as shown in Fig. 6. The value of T chosen will depend on the standards involved in the conversion and the method of conversion adopted but will not be much greater than the duration of the longest

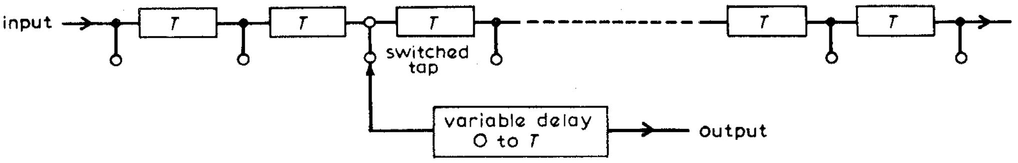


Fig. 6 - Practical equivalent of delay with sliding tap

scanning line involved. The arrangement, although practicable, involves a large number of delays connected in series and would be difficult to instrument. Fortunately, however, it is possible to use a relatively small number of delays to perform the same function as the chain of many small delays. The method proposed consists of an arrangement of delays whose lengths are in binary relationship to each other together with a switching system and the arrangement may thus be termed a "binary delay store".[5]

If the total number of units of delay T required in series is N, the actual delays used would have durations T, 2T, 4T . . . . . 2^nT where 2^n is the nearest power of 2 below N. If N were 250, for example, eight delays of duration T, 2T, 4T, 8T, 16T, 32T, 64T, 128T giving a total of 255T would suffice. It is clear that such a set of delays can provide any integral number of T units from 0 up to $2^{n+1} - 1$ if an appropriate connection and switching system is provided. Fig. 7 shows one means by which this may be achieved and it will be seen in Fig. 7(*a*) that each delay has a corresponding by-pass route, so that signals may traverse that delay or not as required. Each delay and by-pass route is separated from the next by a system of switches which are arranged to make two through connections as shown in Fig. 7(*b*). In one setting, the by-pass routes on either side of the switch are connected together and the delays on either side of the switch are connected together; in the other setting each by-pass route is connected to the delay on the other side of the switch. The arrangement of switches may be conveniently termed "interchange" switching.

As an example of the operation of a binary delay store, Fig. 8 shows how it may replace an arrangement of tapped delays in a field-store converter. It should be noted that in Fig. 8 key letters corresponding to points in the binary store are used; these key letters are defined in Fig. 7. The example assumes that the tapping point is moving away from the input so as to increase the delay from zero towards maximum and Fig. 8(*a*) shows the input signal which is similar to the output of the interpolator of Fig. 3. The input signal of Fig. 8(*a*), which actually comprises two signals from the two interpolator outputs, is divided into numbered sequences each consisting of an integral number of scanning lines of duration T. Each of these sequences overlaps its neighbours by a duration T (i.e., by one scanning line). Thus each sequence must be delayed by one unit of delay T more than the previous sequence so that a continuous stream of scanning lines is obtained. The successive overlapping sequences of the input signal at A_0 B_0 are alternately transmitted through the first delay (of duration T) and through its associated by-pass. Thus at points C_0 and D_0 (after passing through the first delay but before passing through the switch S_1), each odd numbered sequence is undelayed and each even numbered sequence is delayed by T with the result that the overlaps are alternately removed and doubled in duration; this is shown in Fig. 8(*b*). The settings of the switch S_1 are shown in Fig. 8(*c*) and the signal emerging from the switch S_1 (at A_1 B_1) is shown in Fig. 8(*d*). It is seen that the result of the switching operation has been to join together the sequences between which the overlap has been removed; for example, sequences 1 and 2 and 3 and 4 are joined and these new, longer sequences have an overlap of 2T. The next stage of the process, involving transmission through a delay 2T with its associated by-pass and switch S_2, is shown in Figs. 8(*e*), (*f*) and (*g*). It will be seen that this stage results in sequences of four times the original length and with overlaps of 4T appearing at the points A_2 B_2. The process is continued

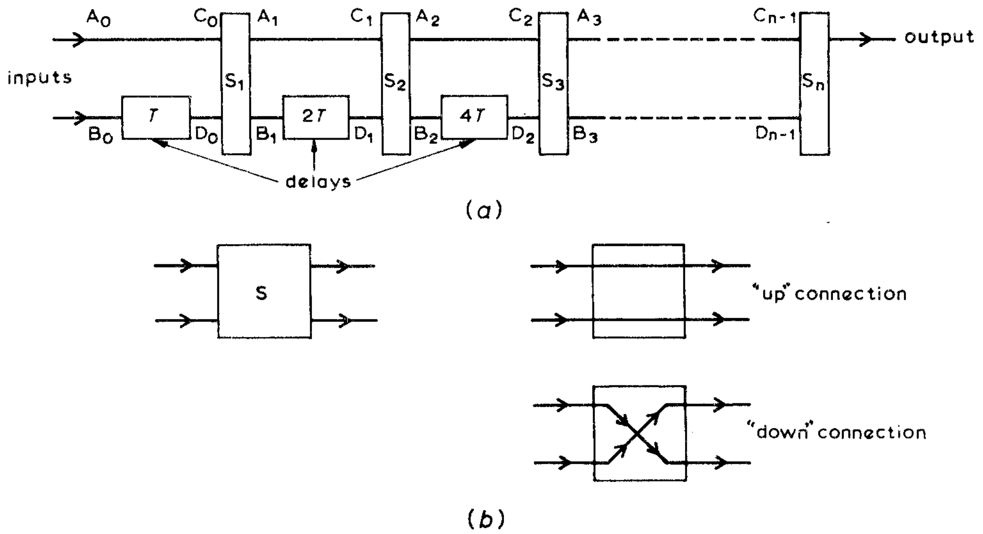


Fig. 7 - Arrangement of binary delay store
(*a*) Arrangement of store
(*b*) Switch connections

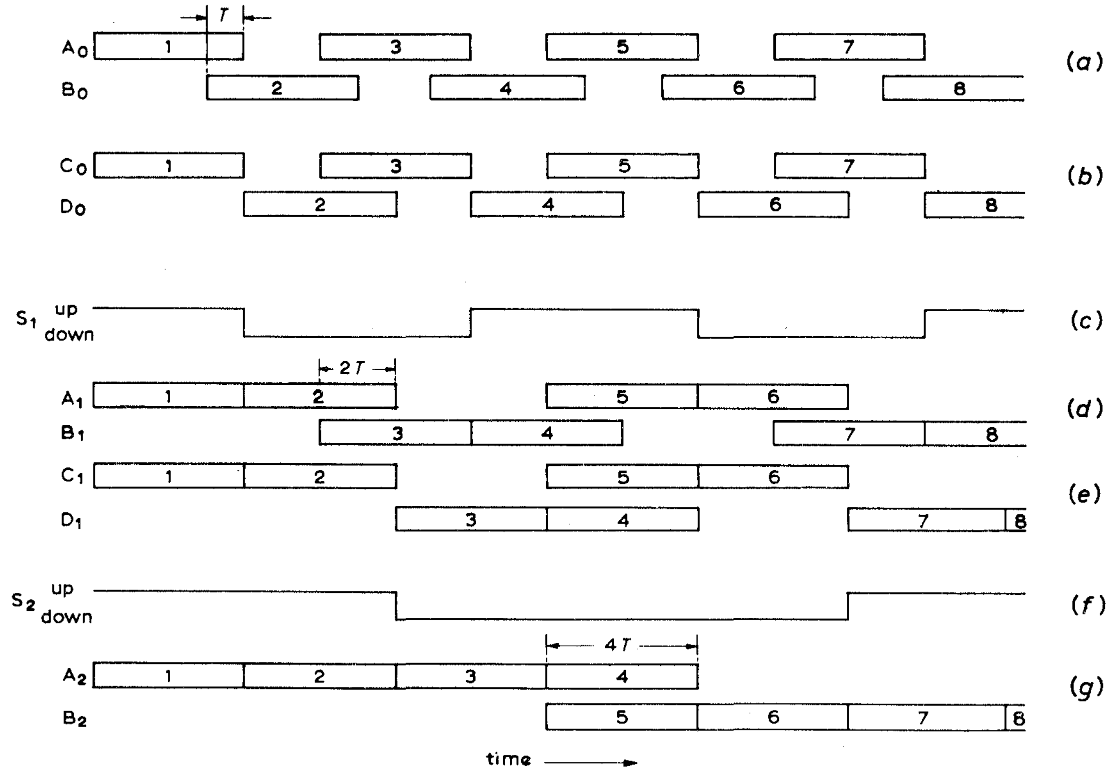


Fig. 8 - Operation of binary delay store

with delays of 4T, 8T, etc. until all the sequences of scanning lines are joined in one continuous sequence and no overlaps remain. The delay may now be returned to zero and as in the case of the delay with sliding tap described in Section 2, the field stored at that moment will be discarded. The mode of operation described is therefore suitable, for example, for a conversion from the 525/60 to the 625/50 standard since extra lines are inserted and fields occasionally discarded.

The principle of operation of the binary delay store is capable of a number of variations[5] which can only be described in outline. The order of the delay units may be reversed so that the signals enter the longest delay first instead of the shortest and the delay is progressively decreased instead of increased. Using this arrangement, sequences of lines with gaps between them can be arranged as a continuous sequence and in addition a field can be stored at intervals for repetition. This mode of operation is therefore suitable for example for a conversion from the 625/50 to the 525/60 standard since lines can be omitted and fields occasionally duplicated. It is important to note, however, that in both modes of operation the binary delay store has two inputs so that two signals can be inserted simultaneously. In conjunction with a variable delay, it can therefore be regarded as equivalent to the two delays with sliding taps shown in Fig. 5.

It is also possible to build a delay store of the type described but to use units whose delays do not have a binary relationship. This property of the delay store is useful since the total delay required may not be that of the sum of a number of binary multiples of the T unit and consequently a binary set of delays may be uneconomic. For example, a binary store giving 300T units would need to have a total delay of 511T whereas a non-binary store of exactly 300T (1, 1, 2, 3, 6, 12, 25, 50, 100, 100) would effect considerable economy. The switching system of a non-binary store is more complicated than in the binary case and certain of the delays required two by-pass routes. The choice of binary or non-binary store will thus be dictated by a compromise between switching complexity and the cost of the fused quartz delays.

5. PRACTICAL FIELD-STORE CONVERTERS

The principles outlined in Sections 2, 3 and 4 can be used as the basis for field-store conversion between any two standards with differing numbers of lines and differing field frequencies. It is, however impossible within the scope of a single report to describe converters for every case that could occur. The case of conversion between the American 525/60 and European 625/50 standards is of particular importance and serves to illustrate most of the problems involved; alternative forms of converter for this particular case of conversion will therefore be described. The proposals all use a "main store"* comprising an arrangement of switched fixed delays based on the principles outlined in Section 4. In order to determine whether the design and construction of practical field-store converters is feasible a comprehensive series of experiments has been carried out to assess the forms of picture impairment associated with the conversion process. These experiments have covered imperfections of interpolation[11] and movement portrayal[12] and distortion due to imperfections in the fused quartz delay units.[13,14,15] The results of this work have indicated that the field-store converters described in this section could be constructed with a performance adequate for operational use.

5.1. Main Store with Ancillary Timing Correction

The proposal[8] is based on the arrangement described in Section 2 in which the complete conversion can be carried out by means of a delay with sliding tap. It must, however, be remembered that the sliding tap is required to move continuously only in order to expand or compress the duration of each line of the input standard to the duration required by the output standard. The operations of inserting or omitting lines and omitting or inserting fields require only that the sliding tap should move in discrete steps. If, therefore, the duration of the lines on the two standards were identical, it would be possible to realise a practical field-store converter using the switched binary delay store described in Section 4 without the variable delay unit.

In the particular case of conversion between the 625/50 and 525/60 standards, the line durations of the two standards, although not identical, are very similar (64 μs and 63 31/63 μs respectively). As a result, a field-store converter using a binary store of switched delays could be designed which would require only a small adjustment of the timing of the output lines in order to give a correct conversion.** The small adjustment of line timing would require only a small storage capacity which could be provided by a relatively simple form of variable delay.

Fig. 9(*a*) shows a block schematic diagram of a possible form of field-store converter for conversion from the 525/60 to the 625/50 standard. The input standard is first passed through an interpolator of the type shown in Fig. 3(*a*) which compensates for the geometrical errors which will be introduced by the insertion of lines in the main store and generates overlapping sequences of lines as shown in Fig. 3(*b*). The output from the interpolator is then passed through the binary main store which consists of an arrangement of fused quartz delays which are switched to arrange the interpolated lines in a continuous sequence and to omit fields as required. Finally, the output of the main store is passed through a variable delay which adjusts the timing of the lines emerging from the main store to that required by the output standard. This variable delay would be automatically controlled by the difference in timing of the lines emerging from the main store and the timing of correctly-timed synchronising pulses at the output standard. The arrangement for the converse conversion from the 625/50 standard to 525/60 standard is shown in Fig. 9(*b*). Here the interpolator will be similar to that shown in Fig. 4(*a*) and the main store is arranged to remove gaps between successive sequences of interpolated scanning lines and to accept additional fields at intervals.

The main store is required to increase or decrease the delay by T each time a line is to be inserted or omitted. It is important to realise, however, that the delay T will not be equal to the duration of a line on either standard. The conversion process requires that the number of increments or decrements of delay is equal to the number of lines which must be inserted or omitted during one complete cycle of the process. This is equivalent to saying that the increment of delay between taps must be equal to:

$$T = \frac{\text{difference in field durations of the two standards}}{\text{difference in number of lines per field of the two standards}}$$

In the case of conversion between the 525/60 and 625/50 standards T is equal to 66.2/3 μs.

5.2. Main Store with Ancillary Line-Store Converter

This proposal[8] is based on the arrangement described in Section 2 in which conversion between standards with different numbers of lines and different field frequencies is achieved by a delay with sliding tap followed by a line-store converter. It is perhaps worth reiterating, however, that satisfactory interpolation is more difficult to achieve in this case. Such an arrangement could however be realised in practice by replacing the delay with sliding tap by a main store using switched fixed delays and converters of this type for 525/60 to 625/50 conversion and 625/50 to 525/60 conversion are shown schematically in Figs. 10(*a*) and 10(*b*) respectively.

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* It is convenient to use the term "main store" to denote the arrangement of binary or non-binary switched fixed delays. This avoids confusion with any ancillary storage used (for example, the storage provided by an ancillary line-store converter)

** Because of the difference in line duration at the input and output standards there will be a cyclic error in timing of the scanning lines emerging from the main store. There will, in addition, be errors in timing due to instrumental imperfections.

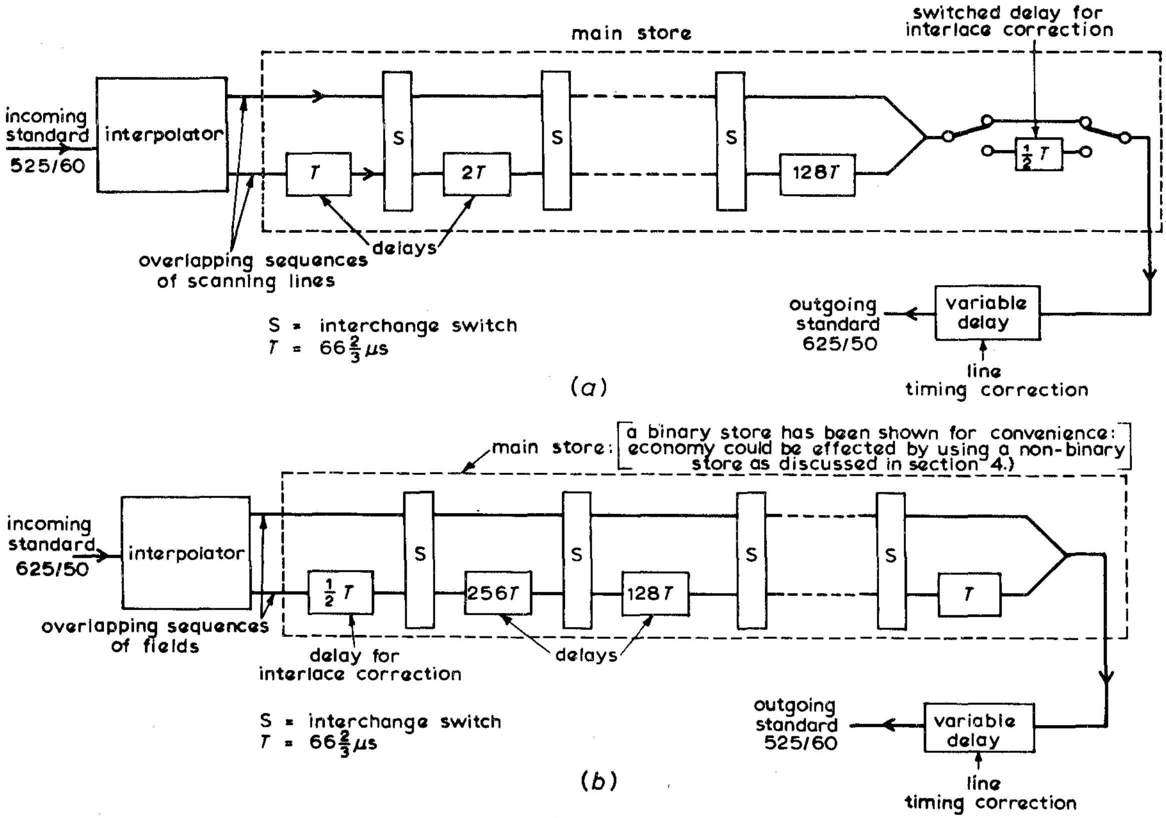

Fig. 9 • *Conversion by main store and timing correction*

(*a*) 525/60 to 625/50 converter
(*b*) 625/50 to 525/60 converter

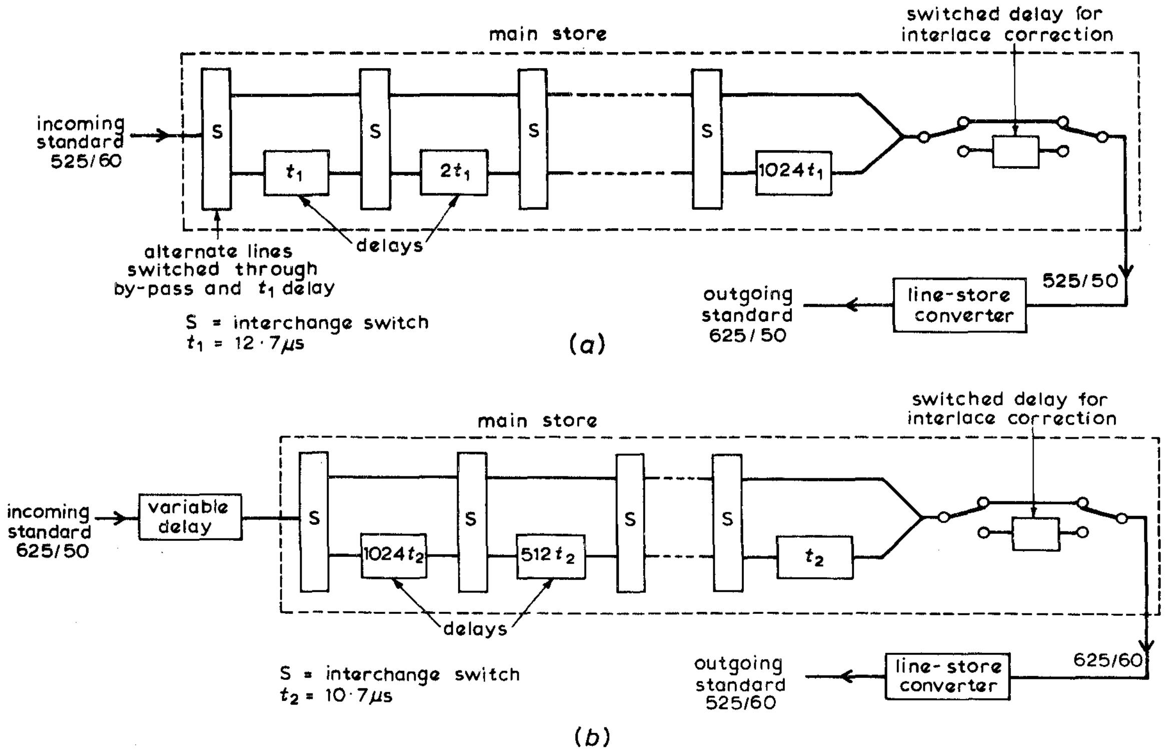

Fig. 10 • *Conversion by main store and ancillary line store converter*

(*a*) 525/60 to 625/50 converter
(*b*) 625/50 to 525/60 converter

It is convenient to consider first conversion from the 525/60 to the 625/50 standard by the arrangement shown in Fig. 10(*a*), and to suppose that the delay of the main store is zero at the beginning of the first of a sequence of six input fields. The delay of the main store is now progressively increased, so that each scanning line is delayed 12·7 μs more than the preceding scanning line. The number of lines thus remains unchanged, but the line-blanking intervals are increased by 12·7 μs, so that the interval between successive line-synchronising pulses is increased from (approximately) 63·5 μs to 76·2 μs. This results in an increase of the duration of each field from 16.2/3 ms to 20 ms as required for the 625/50 standard. The main store thus converts the signal from the original 525/60 standard to a 525/50 standard which is then passed through a line-store converter which converts the 525/50 standard to the 625/50 standard, at the same time restoring the required ratio of line-blanking interval to line duration. The first five input fields, modified in duration and number of lines, become the first five output fields. However, at the end of the fifth output field the sixth input field is completely stored in the main store and can thus be omitted by resetting the delay to zero. The cycle is then repeated and a sequence of five output fields is generated from every sequence of six input fields.

The arrangement for the converse conversion from 625/50 to 525/60 is shown in Fig. 10(*b*). In this case, the delay of the main store is at a maximum at the commencement of a cycle of six output fields. Each line-blanking interval is now reduced in duration by the removal of a delay of 10·7 μs from the main store and by this means the duration of each field is reduced from 20 ms to 16.2/3 ms (as required for the 525/60 standard). The number of lines remains unchanged and the 625/50 standard generated by the main store is then converted to the required 525/60 standard by the line-store converter, which also restores the correct ratio of line-blanking interval to line duration. At the end of the fifth output field the fifth input field is completely stored in the main store and can thus be repeated by switching the delay to a maximum. The cycle is then repeated, giving a sequence of six output fields for each sequence of five input fields.

6. FIELD-STORE CONVERTERS FOR OPERATIONAL USE

6.1. Variation of Field Frequency

The two types of field-store converter described in Section 5 would be suitable for applications in which the input and output field frequencies are precisely in the ratio 5 : 6 or 6 : 5 and are maintained accurately at 50 and 60 cycles/second. The converters would thus be suitable for applications in which either the input (or output) field frequency could be regarded as the master and derived from a stable source; the output (or input) field frequency would then be derived from it. The converters would not convert mains-locked signals, but it should be noted that mains-locked signals recorded on video tape could be replayed locked to a stable source. However, the restriction imposed by the need to maintain a precise ratio between stable input and output field frequencies could be removed.[8,9] In the arrangements of Fig. 9, it would be necessary for the variable delay used for line-timing correction to have a storage capacity approximately equal to that of a scanning line. The field-store converter could then be programmed to correct the timing of the output scanning lines when both the input and output field frequencies vary. In the arrangements shown in Fig. 10 adequate storage capacity is available in the line-store converter and the field-store converter could be programmed in a similar manner. These modified proposals could then accept signals whose field frequencies are not locked in the ratio 6 : 5, so that either or both field frequencies could depart from their nominal values and the output of such converters could be slave-locked. The modification would require an increase in the cost and complexity of a field-store converter, but would result in apparatus capable of handling any operational requirement likely to occur in practice.

6.2. Conversion of Colour Television Pictures

There is little doubt that ultimately field-store converters for the conversion of colour television pictures will be required. A study of this aspect of field-store converter has been made and it seems probable that the forms of converter shown in Figs. 9 and 10 could be used as the basis for practical apparatus for the conversion of colour television signals. It would be possible, for example, though perhaps unnecessarily expensive, to convert separately the luminance and chrominance signals in two or even three field-store converters. However, a less expensive system could probably be developed in which the luminance and chrominance signals were first separated and then separately interpolated. The chrominance signal could then be remodulated to the required output subcarrier frequency and re-combined with the luminance signal. The composite signal could be transmitted to the main store to be re-timed and synchronised with the output standard.

7. CONCLUSIONS

In this report the principles of operation and the design of apparatus for conversion between television standards having different field frequencies and different numbers of scanning lines without the use of a cathode-ray tube/camera combination are discussed. Two basic methods are described which use fused quartz ultrasonic delays as the storage medium:

(i) A converter using a binary main store in conjunction with an ancillary variable delay. The main store would convert both the field frequency and number of lines and the ancillary variable delay would correct the timing of the output scanning lines.

(ii) A converter using a binary main store in conjunction with an ancillary line-store converter. The binary main store would convert the field frequency and the ancillary line-store converter would convert the number of scanning lines.

In their basic form these converters would be suitable for conversion between standards having a fixed ratio between the input and output field frequencies. However, at the cost of some additional complication, both proposals could be extended so that variation of the input and output field frequencies could be permitted.

A field-store converter would have a significant advantage over an image transfer converter in that it would require little or no maintenance and setting-up and would eradicate movement blur and poor resolution. However, in order to eradicate geometrical distortion and jerkiness of motion in the converted picture relatively complicated interpolation arrangements are required. These problems of interpolation can be overcome more easily in the type of field-store converter which does not use a line-store converter.

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